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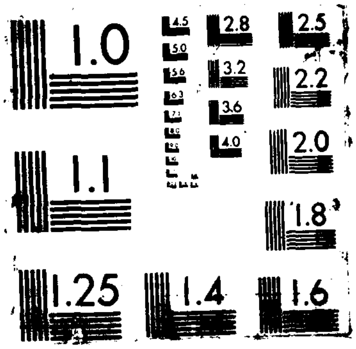
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AD-A195 837

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Special Report 88-5

April 1988

US Army Corps of Engineers

Cold Regions Research & Engineering Laboratory

Development of the unsurfaced roads rating methodology

Robert A. Eaton

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A method for rating the surface drainage and conditions of unpaved roads has been developed, and a field manual has been prepared to assist county, municipal, military and township highway agencies in managing the maintenance of such roads. The types of distress found in unpaved roads are categorized and listed in the manual. For each type of distress listed, there is a description of the distress and the levels of severity, an illustration, and a measurement method. The manual also includes instructions on how to inspect unsurfaced road conditions, a field inspection work sheet, and a family of "deduct value" curves for the distress types and associated severity levels. The curves were validated using data gathered during seven field surveys throughout the United States. This report describes the development of the deduct value curves for the seven distresses identified in unsurfaced road maintenance. The development of the original curves and the adjustments after each field trip are described. The surface and drainage rating method and maintenance management strategies can be used alone, or they can be adapted for use with any existing computerized pavement management system (PMS). The rating method and strategies are compatible with the PAVER PMS developed by the U.S. Army Corps of Engineers and the American Public

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19. Abstract (cont'd)

Works Association. With appropriate software modifications, an unsurfaced roads component of the PAVER PMS will be available for use, giving local highway agencies a more comprehensive roadway management system. (SDW)

PREFACE

This report was prepared by Robert A. Eaton, Research Civil Engineer, Experimental Engineering Division, U.S. Army Cold Regions Research and Engineering Laboratory.

Funding for this project was provided by the Federal Highway Administration Rural Transportation Assistance Program Contract No. DTFH61-84-Y-00891 Project No. 29 "Revising the PAVER Pavement Management System for Use on Unpaved Roads;" U.S. Army Training and Doctrine Command; U.S. Army Facilities Engineering Support Agency; U.S. Army Forces Command; and Office of the Chief of Engineers.

The author thanks Gunars Abele and Vincent Janoo for their technical reviews, and all workshop panel members, field raters and steering committee members.

Special thanks go to Sidney Gerard of Science and Technology Corporation, Hanover, N.H.; Ronald Dattilo, Federal Highway Administration, McLean, Va.; and S. Alford, R. Beaucham, W. Benton, E. Blackmon, J. Glenn, R. Hauger, J. Houston, N.J. LeBrun, K. Leland, R. McDeavitt, F. Oler, R. Stith and W. Wilkerson for their participation in the field validation phase of this project.

Development of the Unsurfaced Roads Rating Methodology

ROBERT A. EATON

INTRODUCTION

About two-thirds of the highway system in the United States and 90% of all roads worldwide are unsurfaced or lightly surfaced low-volume roads. There is no single recognized management system being used to maintain these roads. The United States Army Corps of Engineers, the American Public Works Association, and others have developed pavement management systems (PMSs) for use on paved roads. Until recently these PMSs could not be used for unsurfaced roads. Local highway agencies have needed an unsurfaced road component that can stand alone or be used with any of these PMSs to provide a comprehensive roadway management system more suitable for their needs. This report describes a project that developed a method for rating and managing the maintenance of unsurfaced roads.

The research effort was divided into three phases: Phase I, field manual development; Phase II, field validation; and Phase III, method implementation and development of software. This report describes Phase II. The final field manual has been published by Eaton et al. (1987).

Phase I was the development of a field manual for rating the condition of unsurfaced low-volume roads. Maintenance management practices employed by townships, the military, and municipal, county and state governments were used to develop this rating system. The effort also focused on past and present maintenance practices and field surveys of unsurfaced road distress types. Phase I was funded through the FHWA Rural Technical Assistance Program (RTAP). The research study work has been conducted under RTAP Project No. 29: "Revising the PAVER Pavement Management System for Use on Unpaved Roads."

As a result of the Phase I study, the Phase II field validation effort was approved and initiated. Phase II was a series of field surveys directed at validating the field manual. These surveys provided the information required to define and describe the distress types and their associated severity levels. In addition the surveys provided the data needed to develop the deduct values associated with each distress and severity level.* The Phase II work was jointly funded through an extension of RTAP Project No. 29 and by contributions from several U.S. Army agencies. To coordinate the work activities in Phase II, an executive steering committee was formed by the principal funding agencies. This committee included representatives from the U.S. Army's Facilities Engineering Support Agency, Forces Command, Office of the Chief of Engineers, Training Command, and Corps of Engineers research laboratories (CERL, CRREL and WES), and the Federal Highway Administration. A representative of the Vermont Local Roads Program RTAP Center was also a liaison member. The actual field validation was performed at military installations and nearby areas. The sites represented various unpaved road soil and surface aggregate conditions, environmental conditions, and degrees of maintenance. The sites were located in Kentucky, Georgia, Oklahoma, Arkansas, New Hampshire, Vermont, California, Washington and Alaska. Representatives of the military installations and local areas have used the Phase I prototype method and manual to ensure that the unpaved road distress types, severity levels and deduct value curves are accurate and repeatable.

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* A distress is an undesirable road condition. A deduct value is a measure of the severity of a distress, with 0 indicating that the distress has no impact on road conditios and 100 indicating that the distress has caused the road to fail. The terms are compatible with PAVER.

FIELD MANUAL DEVELOPMENT

The field condition rating manual was based on the following

- An extensive literature search on the design, construction, operation and maintenance of unsurfaced roads
- A series of workshops with unsurfaced road experts from New England.
- Discussions with local, state, federal and university personnel.
- On-site field trips to survey unsurfaced road distresses, how these problems manifest themselves, and what maintenance strategies are used to combat them.

First, an extensive review was conducted of available published information on operations and maintenance practices, maintenance management systems, construction and design, and traffic volumes and loads of unsurfaced low-volume roads. The literature search included a thorough review of documents, reports, manuals and fact sheets prepared by a wide spectrum of organizations, including the Transportation Research Board, Federal Highway Administration, United States Department of Agriculture's Forest Service, U.S. Army Corps of Engineers Construction Engineering Research Laboratory, New Hampshire Department of Transportation, U.S. Army Facilities Engineering Support Agency, American Public Works Association, and Vermont Local Roads Program. These documents provided a good background for the workshops and ensured that the rating and maintenance management system developed for unsurfaced roads was compatible with existing methods, procedures and systems. Based on this review it became apparent that this effort was not duplicating previous or ongoing efforts and that it was worthwhile.

There were three workshops held with New Hampshire and Vermont local and state highway agency personnel, using the Delphi panel technique. (A Delphi panel is a group of experts on a subject brought together to discuss and document an area of concern.) The purpose of the workshops was to prepare a preliminary draft of the distress rating and identification manual to be used in Phase II. The results of the panel's efforts were documented in an unpublished project report. In addition, the panel discussed many other topics related to construction, operation and maintenance of unsurfaced roads. These three workshops provided the major contributions to the manual. They provided background on how unsurfaced roads are currently being maintained; identified and categorized the unsurfaced road distresses; identified some economic, political and social problems; and outlined the information that should be in the manual. Another major goal of the workshops was to present the information so that it could be readily understood and would benefit highway personnel both in maintaining their roads and in conducting their budget reviews.

FINAL FIELD MANUAL

Phases I and II resulted in the publication of a field manual (Eaton et al. 1987). The manual explains how to do a field inspection and calculate the Unsurfaced Road Condition Index (URCI), which is a measure of the road's overall condition and which corresponds to the Pavement Condition Index used in PAVER.

The field inspections consist of "windshield" inspections and detailed measurements. Windshield inspections consist of driving the full length of an unsurfaced road at 25 mph to determine the overall surface and drainage conditions four times a year (once each season). General estimates of maintenance needs and priorities can be made from this initial inspection. Measurements are the collection of detailed data on the roadway's surface and drainage conditions. After the initial inspection ride, a representative section of road 100 feet long is selected where actual measurements of distresses will be taken. The section should be permanently marked so that future measurements will be taken in exactly the same location.

The Phase I field manual identified six unsurfaced road distresses and two drainage-related distresses, each with a separate index. As a result of the Phase II field validation, the two indices were combined. The manual currently lists the following seven distresses:

1. Improper cross section
2. Inadequate roadside drainage
3. Corrugations
4. Dust
5. Potholes
6. Rutting
7. Loose aggregate.

For each distress the severity and density are measured, and the deduct value is determined from graphs. The URCI can then be determined from all the deduct values.

DEDUCT VALUE CURVES

Curve development

As this method was to be compatible with the PAVER pavement managment system, the deduct value curves for corrugations, potholes and rutting and the total deduct value curves for asphalt (U.S. Army 1982) were used as a starting point for the development of curves for unsurfaced roads. Based on these curves and engineering judgment, the initial set of deduct value curves was developed (Appendix A). The workshop discussions established the relative importance of each distress.

The initial field validation survey team, composed of eight members, met at Ft. Knox and Hardin County, Kentucky, on 3-5 June 1986. Twelve 100-ft road sample units were selected for evaluation and measurement. Using qualitative observations, each member of the team rated the section on a scale of 0–100. Each team member also assessed the distresses in each sample unit so that ratings could be computed based on the initial deduct values. Three sample units were inspected and measured by the entire team and used for team member training purposes. The remaining nine sample units were inspected and measured by each team member separately.

After the initial field survey the team members discussed possible changes to the methodology and established the ranking order of the distresses. Their conclusions were

- The methodology is feasible, and personnel can be easily trained to use the manual in the field.
- The distress Loose Aggregate/Dust should be split into two separate distresses, since they are independent.
- The distress Soft Spots/Surface Heaving/Settlements is not required because other distresses accounted for the road problems described by this distress. (The distress was eventually deleted.)
- The distress Drainage (Roadway-Ponding/Erosion) should be changed to Improper Cross Section. This would account for drainage problems on the road surface, even when there was no evidence of water during the inspection.
- The order of importance of each distress on the road condition is summarized in Table 1. Improper Cross Section and Roadside Drainage are themost critical distresses in maintaining a high-quality unsurfaced road.

The data from the initial survey measurements were analyzed, and URCIs were computed. Although the computed URCIs based on the individual distress deduct value curves (Appendix A) were consistent relative to the visual estimates, they were significantly lower. The deduct values were reduced proportionally to match the visual ratings. This provided a data point for each distress type, severity level, density, team member and sample unit.

The accuracy of this method of generating the new deduct value curves depended on the number of data points and the consistency of the adjusted values for each distress and severity level combination. Wherever possible, regression analyses were performed, and a new set of adjusted deduct value curves were developed. Another technique was to use the average value

Table 1. Unsurfaced road distress ranking order.

	Ranking by distress type						
Panel member	*Improper cross section*	*Roadside drainage*	*Potholes*	*Dust*	*Corrugations*	*Rutting*	*Loose aggregate*
A	1	2	4	3	5	6	7
B	5	1	2	4	3	6	7
C	1	2	3	5	6	4	7
D	1	2	4	3	6	5	7
E	1	2	4	3	5	6	7
F	1	2	3	6	5	4	7
G	1	2	3	6	5	4	7
H	2	1	3	5	4	6	7
Total	13	14	26	35	39	41	56
Average ranking	1.63	1.75	3.25	4.38	4.88	5.13	7.00

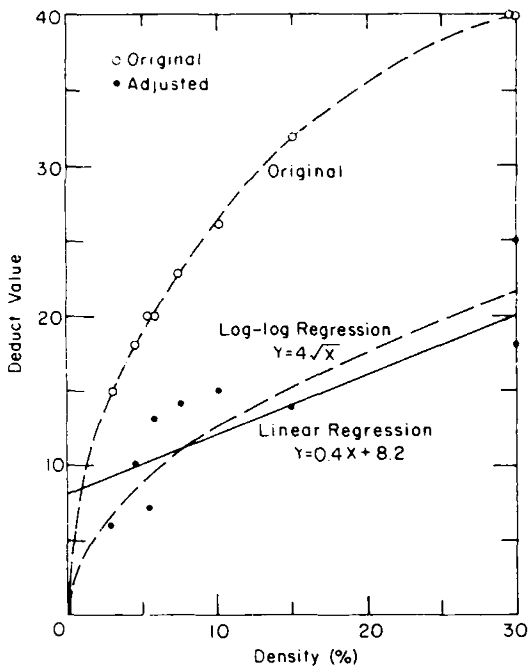


Figure 1. Best-fit lines for the original deduct values, the linear regression, and the log–log regression.

Table 2. Original and adjusted deduct values for rutting at low severity.

Density (%)	*Original deduct value*	*Adjusted deduct values*
3.0	15	6
4.5	18	10
5.4	20	7
5.6	20	13
7.5	23	14
10.2	26	15
15.0	32	14
30.0	40	25
30.0	40	18

and engineering judgment to determine the best fit for the data and then to extrapolate between low, medium and high severity levels within a distress.

An example of how regression analysis was used is presented for the rutting distress at low severity. Table 2 shows the data gathered during the Ft. Knox field survey. A linear regression was performed on the adjusted deduct values (y) versus the percent density. A correlation coefficient of 0.87 was obtained, which indicates a reasonably good fit for the regression line $y = 0.4x + 8.2$. This equation was used to estimate the new set of adjusted deduct values for low-severity rutting distress.

In addition to the linear regression analysis performed on the adjusted deduct values, a log–log regression analysis was also performed for comparative purposes. The log–log regression produced a correlation coefficient of 0.88 with a regression line of $y = 4.3x + 0.48$. By making the slope $n = 1/2$ and forcing the line through the mean ($x = 9.1$; $y = 12.5$), the log–log regression line can be approximated by the equation $y = 4x$. Figure 1 presents the best fits for the original deduct values, the linear regression ($y = 0.4x + 8.2$) and the log–log regression ($y = 4x$).

The adjusted deduct value curves were used for computing URCIs in the subsequent field surveys. The final deduct value curves are presented in Appendix B. The seven field surveys produced a large data base for comparing visual and deduct value ratings. Table 3 and Figure 2 show the results of these comparisons. Table 3 presents the mean difference between the visual ratings and the deduct value ratings, which ranged from 0.1 to 3.9, with an overall mean difference of 1.4 points for all survey locations. The standard deviation of these mean differences ranged from 4.2 to 9.8 points; the standard deviation for allocations from sample unit to sample unit was 5.8. Table 3 also presents the standard deviation of deduct value ratings from team member to team member; these ranged from 4.8 to 8.3 points, with an overall location dispersion of 6.3.

Figure 2 shows the correlation of visual ratings and deduct value ratings. Figure 2 shows that the correlation is strong between the visual and the computed URCI. This means that the methodology is quite consistent for different locations within the United States and for different raters with varying backgrounds and capabilities.

Curve evaluation

During the development of the deduct values and the overall unsurfaced road methodology,

Table 3. Data analysis results.

Location	$\bar{X}y-\bar{X}c$*	$S_{\bar{X}y-\bar{X}c}$†	S_r**
Ft. Knox, Kentucky	1.2	9.8	7.2
Ft. Stewart, Georgia	0.1	5.2	6.2
Tulsa, Oklahoma	3.9	6.9	4.8
Vermont/New Hampshire	0.2	6.2	6.5
Ft. Irwin, California	1.0	4.2	8.3
Ft. Lewis, Washington	1.7	6.3	8.2
Alaska	2.7	4.3	6.2

* The mean difference between the visual ratings and the deduct value ratings.

† The standard deviation of the mean difference between the visual observations and the computed ratings.

** The standard deviation of the computed ratings from team member to team member within a road section. This estimate how consistent the computed ratings (deduct values) are between various peoples.

some analyses were performed to assess the impact of a number of factors on the deduct values and ultimately on the overall rating of an unsurfaced road. These factors were density variations, the severity levels within a distress type, and the number of distresses present in a sample unit.

It is evident from the deduct value curves that as the density and severity of a distress increase, the deduct value increases. Since the distresses and how they are measured are extremely diverse, it is difficult to compare the impact of the density of a distress on the deduct value. Table 4 shows the densities that would produce deduct values of 10 and 20 for each distress type and severity level.

The severity of a distress in a sample unit is important to the overall rating of the road. The deduct value is higher for high severity than for medium or low severity of the same distress, if the density is the same. Table 5 shows the impact of severity level on deduct values. Going from low to medium severity generally results in a 50% increase in deduct value. Going from medium to high results in increases between 33% and 50%. Going from low to high yields increases of approximately 100%.

The rating of an unsurfaced road depends on the distresses present, the density of each distress, the severity level of each distress and the number of distress-severity combinations with deduct values greater than 5 can significantly affect the final rating since distresses are interactive and result in double counting of deduct values if multiple distresses are present in the sample unit. Therefore, a series of empirical relationships that were developed for asphalt roads are now being used for unsurfaced roads. Figure 3 shows how this fact is taken into consideration. This curve shows the Corrected Deduct Values (CDV) as a function of q and Total Deduct Values (TDV). Table 6 shows the possible effect of q (for a constant TDV) on the overall rating of an unsurfaced road.

Final curve adjustment

After the field manual was published, the accumulated deduct value data were used to generate new curves using a computerized curve-fitting routine. The equations determined by the computer produce curves that vary by less than 10% from the previously determined curves. The new curves will be included in future revisions of the manual.

Table 4. Effect of density on deduct values.

Distress type	*Density (%) producing deduct values of 10*			*Density (%) producing deduct values of 20*		
	Low severity	*Medium severity*	*High severity*	*Low severity*	*Medium severity*	*High severity*
1. Improper cross section	4.5	3.5	2.5	10	7	5
2. Inadequate roadside drainage	7	4	2.5	16	9	7
3. Corrugations	16	10	7	36	27	19
4. Dust	not a function of density			not a function of density		
5. Potholes	0.5	3	2	1.4	0.7	0.8
6. Rutting	4	3	2	19	11	8
7. Loose aggregate	6	3	2.2	<20	12	5

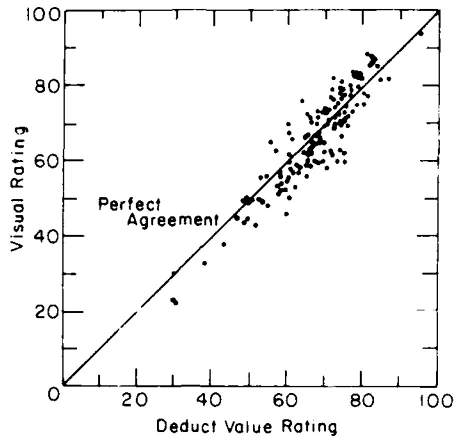


Figure 2. Comparison of visual ratings and computed ratings.

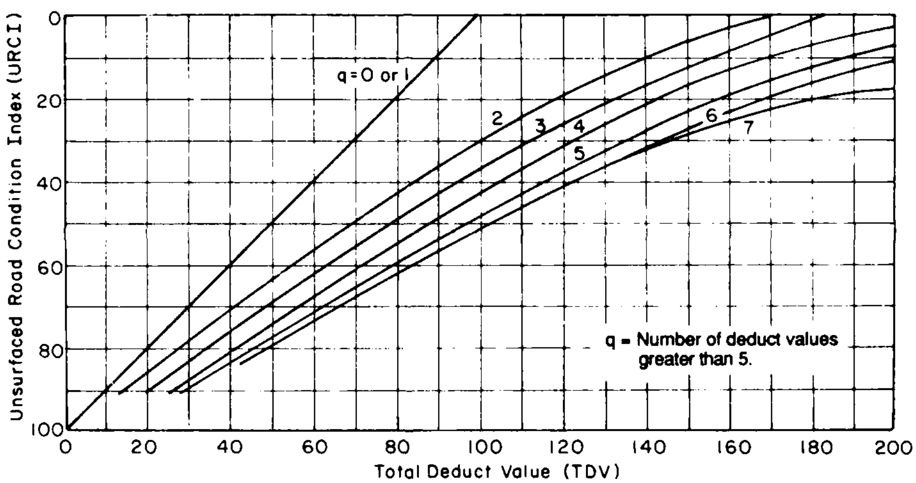


Figure 3. Unsurfaced Road Condition Index as a function of q *and the Total Deduct Value.*

Table 5. Effect of severity level on deduct values.

Distress type	*Density (%)*	*Severity level*		
		Low	*Medium*	*High*
1. Improper cross section	5.0	11	15	20
2. Roadside drainage	5.0	8	12	17
3. Corrugations	10.0	6	9	12
4. Dust	*	2	5	15
5. Potholes	1.0	17	26	42
6. Rutting	10.0	15	17	22
7. Loose aggregate	5.0	9	12	20

* Not applicable.

Table 6. Effect of number of distresses.

	Road A Distress values				Road B Distress values				Road C Distres values			
Distress type	*L*	*M*	*H*	*Total*	*L*	*M*	*H*	*Total*	*L*	*M*	*H*	*Total*
1. Improper cross section	6	3	3	12	6	3	3	12	6	6	—	12
2. Roadside drainage	4	4	4	12	6	3	3	12	6	3	3	12
3. Corrugations	4	4	4	12	4	4	4	12	6	3	3	12
4. Dust	—	5	—	5	—	5	—	5	—	5	—	5
5. Potholes	4	4	4	12	4	4	4	12	6	3	3	12
6. Rutting	4	4	4	12	4	4	4	12	6	3	3	12
7. Loose aggregate	4	4	4	12	4	4	4	12	6	3	3	12

	Road A	Road B	Road C
	TD = 77	TDV = 77	TDV = 77
	q = 1	q = 2	q = 7
	CDV = 36	CDV = 56	CDV = 36
	URCI = 23	URCI = 44	URCI = 64
	Rating = POOR	Rating = POOR	Rating = POOR

CONCLUSIONS

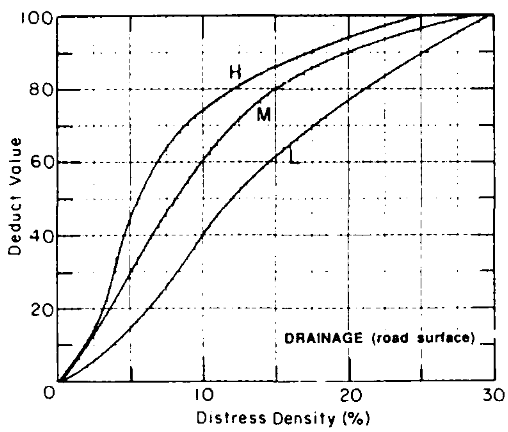
A method for rating unsurfaced roads has been developed and validated in the field at seven areas from New England to Alaska. The data gathered during these field surveys have been analyzed and used to develop deduct values. The analyses indicate that the deduct value method can be effective for rating unsurfaced roads. The mean difference between visual observations and those calculated from the deduct values was 1.4, with a standard deviation of 5.8. In addition, the analyses indicate that the deduct values produce ratings with a difference of 6.3 from road rater to road rater. These mean differences and dispersions are extremely small considering the wide variation in the background and experience of the personnel on the panels, not to mention the tremendous differences in the construction techniques, maintenance policies, materials used and geographic locations of the unsurfaced roads evaluated using this methodology.

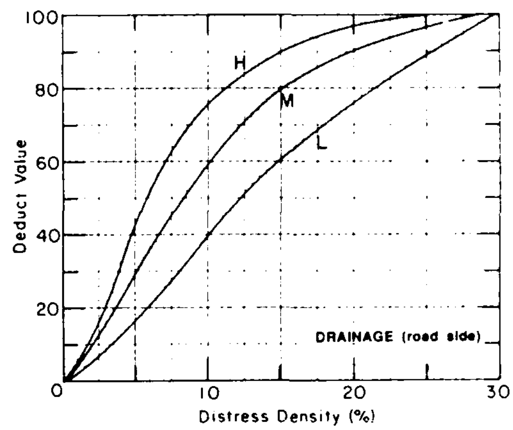
LITERATURE CITED

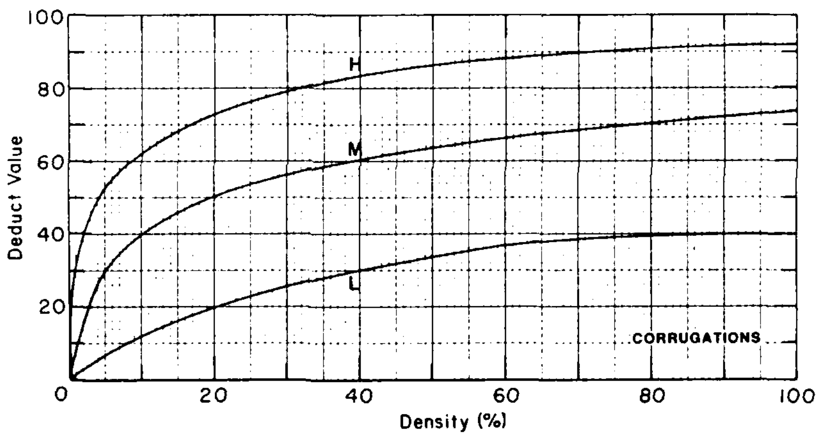
Eaton, R., S. Gerard and D. Cate (1987) Rating unsurfaced roads, A field manual for measuring maintenance problems. USA Cold Regions Research and Engineering Laboratory, Special Report 87-15.

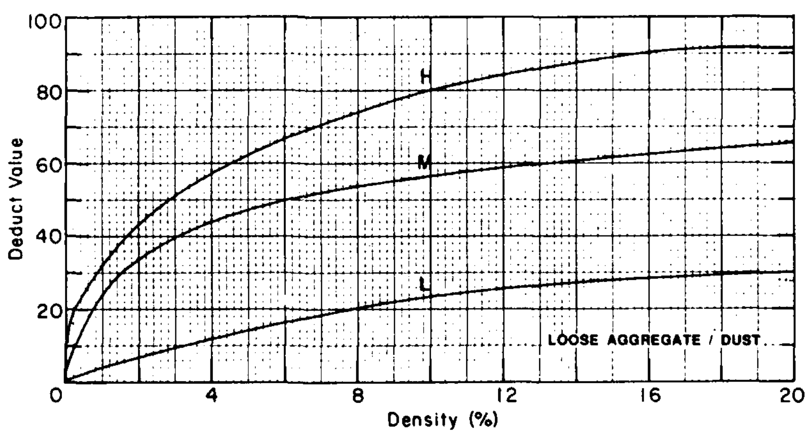
U.S. Army (1982) Pavement maintenance management. Technical Manual 5-623.

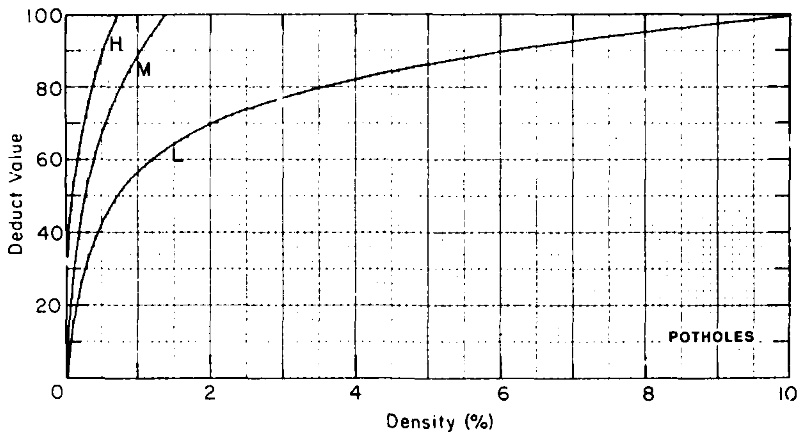
APPENDIX A: ORIGINAL DEDUCT VALUE CURVES FOR FT. KNOX AND HARDIN COUNTY, KENTUCKY







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Deduct Value
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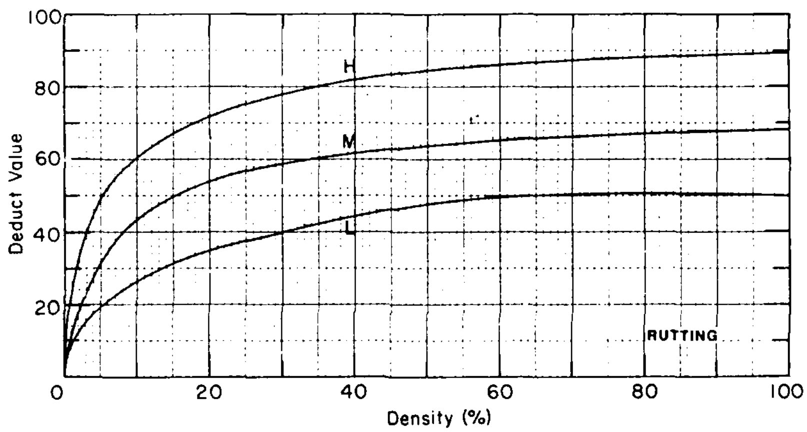
Density (%)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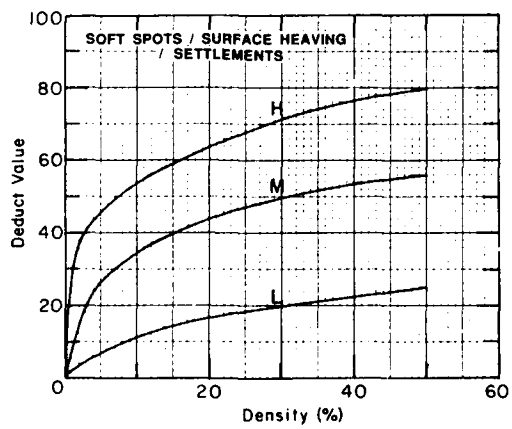
100
80
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20
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Deduct Value
SOFT SPOTS / SURFACE HEAVING / SETTLEMENTS
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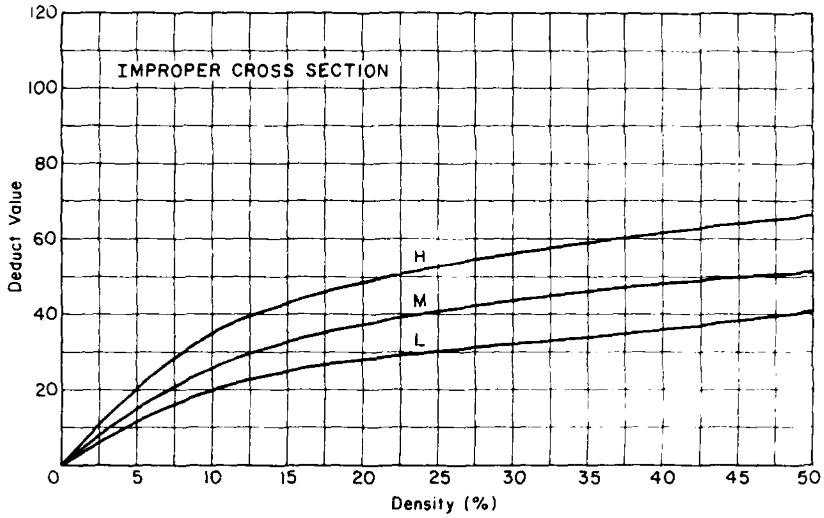
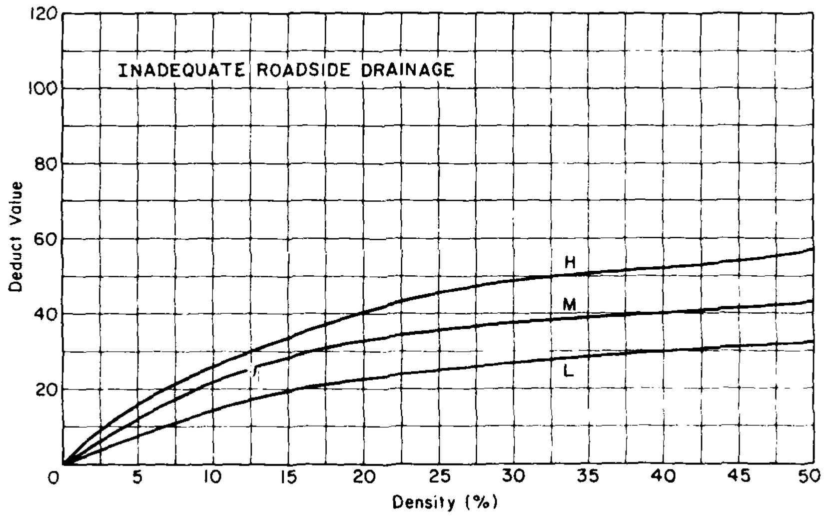
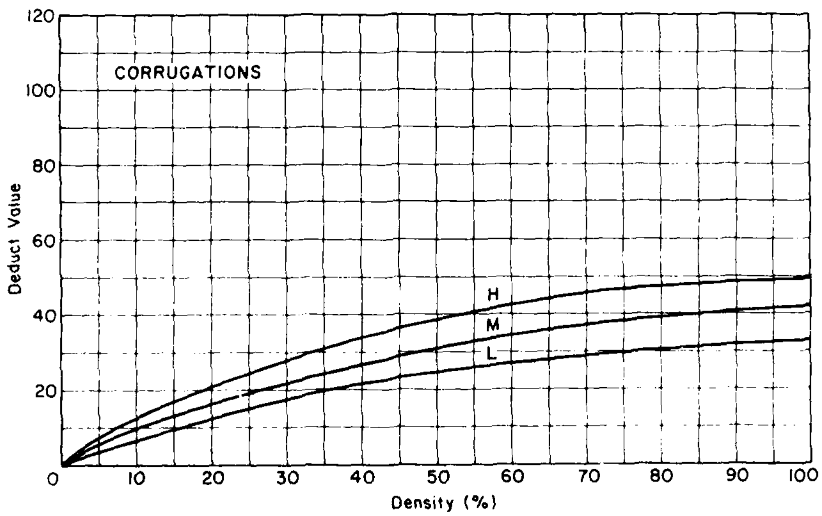
Density (%)

APPENDIX B: FINAL SET OF DEDUCT VALUE CURVES.



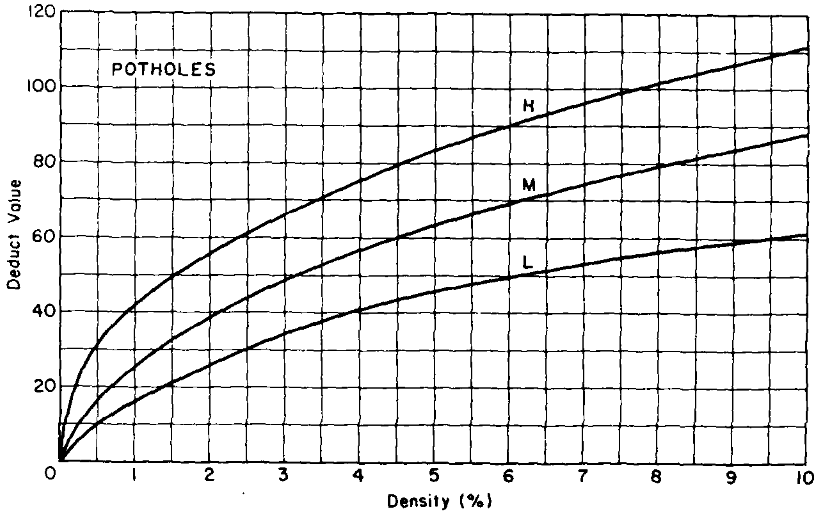


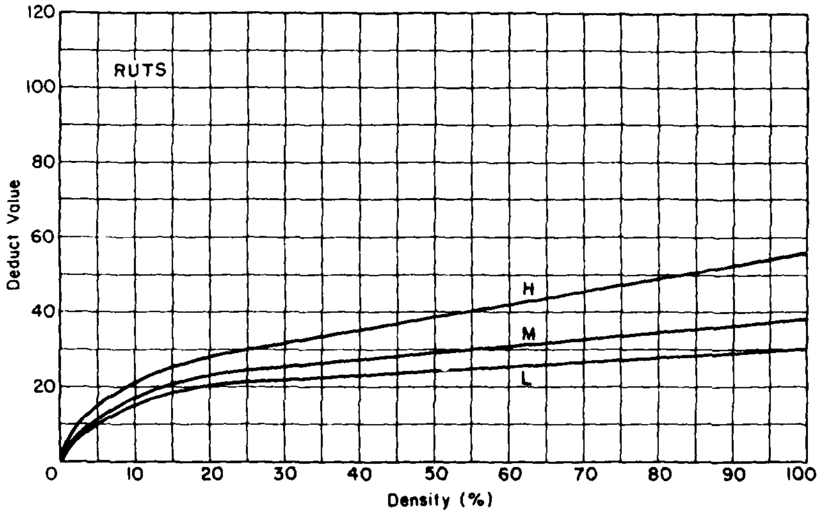


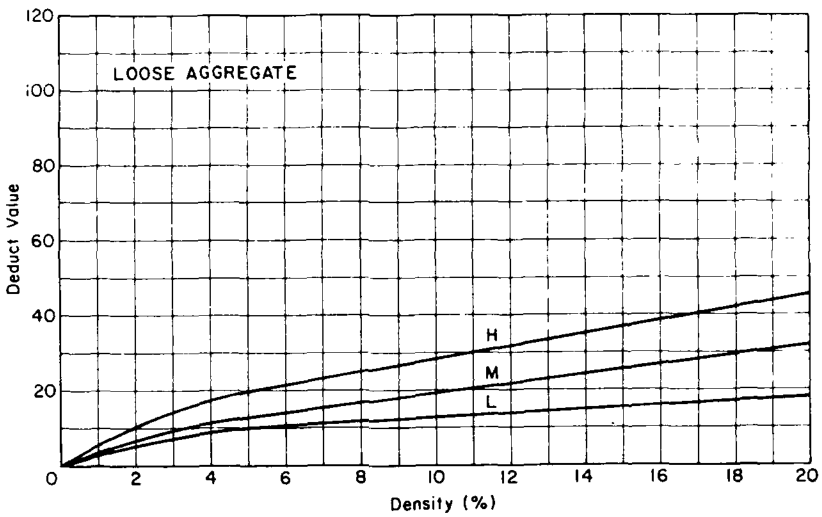
DUST

Dust is not rated by density. The deduct values for the levels of severity are:

LOW	2 points
MEDIUM	5 points
HIGH	15 points






LOOSE AGGREGATE
Deduct Value
120
100
80
60
40
20
0
2
4
6
8
10
12
14
16
18
20
Density (%)
H
M
L

END
DATED
FILM
8-88
DTIC